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Determination of sea-level rise in cape coast, Ghana using extreme value theory

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ABSTRACT

There has been growing concern about global sea-level rise and its impacts on mankind. This work therefore focuses on analyzing sea level data of Cape Coast Sea by employing conventional methods of time series analysis and extreme value theory. The study seeks to find out if there is any significant rise in the sea levels of the Cape Coast Sea that will cause flooding of the town and to make recommendations as to whether resettlement issues should be considered. The exploratory analysis reveals that the sea levels of the Cape Coast Sea are characterized by trend and seasonality. The conventional approach of analyzing the sea level data considered sitting a trend model, trend plus seasonal model, a quadratic trend model and a quadratic plus seasonal model to the sea levels of the Cape Coast Sea. The analysis reveals that the fluctuations in the sea levels of the Cape Coast Sea could best be modeled by a trend plus seasonal model. The estimated parameters of the model reveal a highly significant and positive trend in the sea levels of the Cape Coast Sea, and if this trend continues it will have serious implication for the flooding of the town. The extreme value approach in analyzing the sea levels of the Cape Coast Sea considered sitting a General Extreme Value (GEV) distribution model to the annual maxima sea levels (block maxima approach) and the Generalized Pareto Distribution (GPD) model (threshold model). The fitted GEV distribution that changes linearly in the location parameter(μ (t)) is reasonable in modeling the annual maximum sea levels of the Cape Coast sea levels and this supports the fact that the annual maximum sea levels increases over time. The GPD model on the other hand does not support a linear trend in the scale parameter (σ(t)). On a whole, the estimated parameters of both models show an increase in the sea levels, and this is significant for the flooding of the town.

Introduction

There is a widespread consensus that substantial long-term sea level rise will continue for centuries to come (National Research council of the National Academies, 2010). This work therefore focuses on employing conventional methods of time series analysis and the applications of extreme value theory in analyzing the sea level data in Cape coast, and to compare both methods by assessing any differences and similarities in the use of such methods in analyzing the sea level data. Cape Coast, or *Cabo Corso*, is the capital of the Central Region of Ghana and is also the capital city of the Fante (Fanti) people, or Mfantsefo. It is situated 165 km west of Accra on the Gulf of Guinea. It has a population of 82,291 (2000 census). The main occupation of the people is fishing and most of these fishermen leave near the coast. The objective of the study is to determine whether there is a significant rise in the sea levels that affects Cape coast and to make recommendations as to whether resettlement issues should be considered.

Cape coast, Ghana. View of the fishing fleet

Map of Ghana,indicating cape coast.

Causes of Sea Level Change

Human-induced climate change has been considered as the major cause of sea level rise. There are three major processes in which human-induced climate change directly affects sea level. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC's Fourth Assessment Report,2002) states that the three main processes responsible for sea level rise are, thermal expansion, the melting of glaciers and ice caps, and the loss of ice from the Greenland and West Antarctic ice sheets. The basic principle explaining how thermal expansion causes sea level rise is based on the fact that, when we consider air and other fluids, the density (that is mass per unit volume) goes down when temperature rises. This means that water expands as its temperature increases. In view of this when ocean temperatures increase as a result of climate change initially at

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the surface and over centuries at depth, the water will expand, contributing to sea level rise(IPCC's Fourth Assessment Report, 2002). The report also stated that out of the sea level rise during the second half of the 20th century, thermal expansion might have contributed to about 2.5 cm in global sea level rise, and the rate at which it is rising has almost been tripled in the early parts of the 21st century. This assertion made in the IPCC's Fourth Assessment Report was due to the fact that the contribution of thermal expansion to sea level rise depends mainly on the temperature of the ocean, and that projecting the increase in ocean temperatures provides an estimate of future growth. Over the 21st century, the (IPCC's Fourth Assessment, 2002) projected that thermal expansion will lead to sea level rise of about 17-28 cm (plus or minus about 50%). The second contributor to sea level rise is the melting of glaciers and ice caps. Among the major causes of sea level rise, melting of glaciers and ice caps is considered to be a less certain contributor to sea level rise. (The IPCC's Fourth Assessment Report,2002) estimated that, during the second half of the 20th century, melting of mountain glaciers and ice caps led to about a 2.5 cm rise in sea level. This is a higher amount than what was caused by the loss of ice from the Greenland and Antarctic ice sheets, which added about 1 cm to the sea level. For the 21st century, (IPCC's Fourth Assessment Report, 2002) projected that "melting of glaciers and ice caps will contribute roughly 10-12 cm to sea level rise, with an uncertainty of roughly a third". The last of the major cause of sea level rise is the loss of ice mass from Greenland and Antarctica. (The IPCC Fourth Assessment Report, 2002) made an assertion that even though it will take many centuries to millennia for all the ice on Greenland to melt, if this process is to happen, then sea level is likely to rise by roughly 7 meters. According to reports on the Climate Institute web site (http://www.climate.org/topics/sea-level/index.html), the West Antarctic ice sheet holds about 5m of sea level equivalent and is particularly vulnerable as much of it is grounded below sea level; the East Antarctic ice sheet, which is less vulnerable, holds about 55 m of sea level equivalent". (The IPCC Fourth Assessment Report , 2002) stated that loss of ice mass from Greenland would lead to about a 2cm rise in sea level whereas that of Antarctica would lead to about 2 cm fall in sea level, due to the possibility of increased accumulated effect of snow.

Global Sea Level Rise

It has been said that Global sea level has been rising since the mid-19th century, and this is primarily due to human-induced climate change (IPCC's Fourth Assessment Report, 2002). According to Ghana's Hydrological Services Department, the ocean claims 1.5 – 2 meters of Ghana's 539 kilometer coastline annually, with the most risky areas recording four meters (Kwasi Appeaning Addo et al, 2011). (Warrick et al, 1995) stated that sea level rose about 15-20 cm and this is roughly 1.5 to 2.0 mm/year during the 20th century. (Warrick et al, 1995) made an interesting observation that, the rate of increase in sea level at the end of the 20th century turns out to be greater than the rate during the early part of the 20th century. Satellite measurements taken over the past decade shows that sea level has increased by about 3.1mm/year and this rate is significantly higher than the average rate for the 20th century, even though there is controversy about the likely size of the increase (Consequences of Climate Change on the Oceans, http://www.climate.org/topics/sea-level/index.html). In the executive summary of Climate Change (IPCC Third Assessment Report, 2001) of the current state of knowledge of the rate of change of global average and regional sea level in relation to climate change in the 20th and the 21st century stated that the average rate of sea level rise from tide gauge data has been larger during the 20th century than the 19th century. It goes further to say that the rate of global average sea level rise based on tide gauge data during the 20th century is in the range 1.0 to 2.0 mm/yr, with a central value of 1.5 mm/yr (IPCC Third Assessment Report, 2001). (Warrick et al, 1996) estimated that by "the worst case" scenario, global mean sea level is expected to rise 95 cm by the year 2100, with large local differences due to tides, wind and atmospheric pressure patterns, changes in ocean circulation, vertical movements of continents etc.; the most likely value is in the range from 38 to 55 cm" .In addition, according to a study by Titus and Narayanan, quoted by (CZMS, 1992), indicates that the statistical distribution of sea-level rise exhibits a marked positive skew (i.e. many average values and some very large ones in only a few locations). This is a worrying development since most of the world's coastal cities were established during the last few millennia, a period when global sea level has been nearly constant.

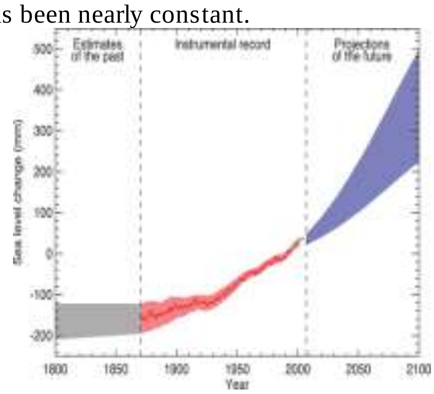

Figure 1: showing the evolution of global mean sea level in the past and as projected for the 21st century for the SRES A1B scenario

Effects of sea level rise

Based on the projected increases stated above, the IPCC TAR WGII report (*Impacts, Adaptation Vulnerability*) notes that current and future climate change would be expected to have a number of impacts, particularly on coastal systems (IPCC Third Assessment Report, 2001)Such impacts may include increased coastal erosion, higher storm-surge flooding, inhibition of primary production processes, more extensive coastal inundation, changes in surface water quality and groundwater characteristics, increased loss of property and coastal habitats, increased flood risk and potential loss of life, loss of nonmonetary cultural resources and values, impacts on agriculture and aquaculture through decline in soil and water quality, and loss of tourism, recreation, and transportation functions. There is an implication that many of these impacts will be detrimental especially for the three-quarters of the world's poor who depend on agriculture systems (human development report, 2007/2008). The report does, however, note that owing to the great diversity of coastal environments; regional and local differences in projected relative sea level and climate changes; and differences in the resilience and adaptive capacity of ecosystems, sectors, and countries, the impacts will be highly variable in time and space. Statistical data on the human impact of sea level rise is scarce. A study in the April, 2007 issue of *Environment and Urbanization* reports that 634 million people live in coastal areas within 30 feet (9.1 m) of sea level. The study also reported that about two thirds of the world's cities with over five million people are located in these low-lying coastal areas. The IPCC report of 2007 estimated that accelerated melting of the Himalayan ice caps and the resulting rise in sea levels would likely increase the severity of flooding in the short term during the rainy season and greatly magnify the impact of tidal storm surges during the cyclone season. A sea-level rise of just 400 mm in the Bay of Bengal would put 11 percent of the Bangladesh's coastal land underwater, creating 7 to 10 million climate refugees.

Methodology

Overview of extreme value theory

Broadly speaking, there are two principal kinds of model for extreme values. The oldest group of models are the *block maxima* models and a more modern group of models are the *peaks-over threshold* (POT) models; these are models for all large observations which exceed a *high* threshold. The POT models are generally considered to be the most useful for practical applications, due to their more efficient use of the (often limited) data on extreme values. (McNeil, 1999). Extreme value theory deals with questions which are related to the probability of the occurrence of very high or very low values in sequences of random variables in a stochastic process (Smith, 2004). Extreme value theory is therefore employed to answer questions that are related to the distribution of extremes (Coles, 2001). For example, what is the probability that the sea level will rise over a given level in a given month? In this situation we are interested in the occurrence of the unusual rather than the usual. Due to this, (Coles, 2001) describes extreme value theory as a unique statistical discipline since it develops techniques and models for the description of the unusual rather than the usual. Extreme value theory provides a framework for which one could estimate or anticipate the occurrence of an unusual event or how well the probability of such an event could be estimated based on available data (Coles, 2001).

The distinguishing feature of an extreme value analysis is the objective to quantify the stochastic behavior of a process at unusually large or small levels (Coles, 2001). According to (Coles, 2001), the analysis based on extreme value theory usually requires estimation of the probability of events that are more extreme than any that have already been observed. For example, as a design for a costal defense, a sea-wall is required to protect all sea levels that are likely to be experienced within a projected lifespan of say 100 years. Local data on the sea levels might be available, but for a shorter period of years, say 10 years. The challenge is to estimate what sea levels might occur over the next 100 years given the 10 years history. Extreme value theory provides the framework that enables extrapolations of this type. It is very difficult to formulate an extrapolating rule since empirical or physical guidelines are not present. (Coles, 2001) holds the view that to be able to formulate an extrapolation rule, standard models must be derived from an asymptotic argument, which in the simple case works as follows: Suppose we denote by X1;X2; ::: the sequence of monthly sea levels, then according to (Coles, 2001) the maximum sea level over an "n-observation" period is given by

$$M_n = \max\{x_1, x_2 ...., x_n\}$$

If we know the exact statistical behavior (distribution) of the X_i, then it will be possible to calculate the corresponding behavior of M_n. Since in practice we do not know the distribution of the X_i, it is impossible to know the exact calculations of the distribution of M_n. However, (Coles, 2001) indicated that a family of models can be calibrated by the observed values of M_n based on detailed limit arguments by letting $n \to \infty$ (i.e., for large values of n). This can be possible if we are able to come out with suitable assumptions in order to approximate the distribution of M_n. This approach according to (Coles, 2001) is termed as the "extreme value paradigm", since it involves the use of mathematical limits as a finite-level approximation for model extrapolation.

Theory

General extreme value (GEV) distribution

This section develops the model which forms the basis of extreme value theory. According to (Coles, 2001) the model focuses on the statistical behavior of $M_n = \max\{X_1, X_2 ......X_n\}$, where $\{X_1, X_2 ....X_n\}$ is a sequence of independent random variables with identical distribution function *F*. The Xi in practice could represent the values of a process measured on a particular time scale such as the monthly sea level recordings and M_n May represent the maximum sea level recordings over n time units. If n is the number of sea level recordings in a year, then M_n may be termed as the annual maximum (Smith, 2004). Theoretically, for all values of n, (Coles, 2001) stated that we can derive the exact distribution of M_n. Such that

$$P_r\{M_n \le z\} = \{F(z)\}^n \qquad (1)$$

Since the distribution function F is unknown, the above equation is practically not helpful. According to (Coles, 2001), one possibility is to estimate *F* from observed data so as to substitute this estimate into equation (1). One worrying situation in this approach is that any small discrepancies in the estimate of *F* can lead to substantial discrepancies for F^n (Coles, 2001). An alternative to this is to look for approximate families of models for F^n, which can be estimated on the basis of the extreme data only (Coles, 2001).

Analogous to the central the limit theorem, then there exist sequences of constants $\{a_n \succ 0\}$ and $\{b_n\}$ (Coles, 2001) such that

$$P_r\left\{\frac{(M_n - b_n)}{a_n} \le z\right\} \to G(z) as \to \infty \qquad (2)$$

where G is a non-degenerative distribution function belonging to one of the following families:

I. Gumber: $$G(z) = \exp\left\{-\exp\left[-\left(\frac{z-b}{a}\right)\right]\right\}, -\infty \prec z \prec \infty; \qquad (3)$$

II. Frechet: $$G(z) = \begin{cases} 0, z \le b \\ \exp\left\{-\left(\frac{z-b}{a}\right)^{-\alpha}\right\} z \succ b; \end{cases} \qquad (4)$$

III.Weibull: $$G(z) = \begin{cases} \exp\left\{-\left[-\left(\frac{z-b}{a}\right)^{\alpha}\right]\right\} z < b \\ 1, z \ge b \end{cases} \qquad (5)$$

for parameters a > 0,b and, in the case of families II and III, α > 0. Collectively, these three classes of distribution are known as the extreme value distributions with each having a scale and location parameters as a and b, respectively. The three types of distributions are combined into a single family of models having distribution functions of the form given by (Coles, 2001) as.

$$G(z) = \exp\left\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-1/\xi}\right\} \qquad (6)$$

defined on the set $\left\{z : 1+\frac{\xi(z-\mu)}{\sigma} > 0\right\}$ where the parameters satisfy $-\infty < \mu < \infty, \sigma > 0$ and $-\infty < \xi < \infty$. The expression in equation (6) is known as the general extreme value (GEV) distribution

Results and discussion

Leveling the sea level time series (first differences of logs)

Stochastic changes in long term level have been noted for the sea level data exhibited in figure 2. A common approach in leveling a time series data is to take the differences of logs between successive values of the series (that is, first differences of logs). According to (Lawrence, 2011), the fractional increase or decrease (growth rate) per month in the sea level is given by

$$r_t = \frac{x_t - x_{t-1}}{x_{t-1}}, t = 1,2,\ldots\ldots\ldots\ldots \qquad (7)$$

According to (Lawrence, 2011) the growth rate (r_{tt}) can be written as the first differences of logs of x_t given by

$$lr_t = \log(x_t) - \log(x_{t-1}) \qquad (8)$$

(Lawrence, 2011) justified the expression of lr_t through the following illustrations:

If we let r_t to be the instantaneous growth rate per unit time (month) at time t, and x_t (monthly sea levels) is continuous at time t, then

$$r_t' = \frac{x_{t+dt} - x_t}{x_t dt} \qquad (9)$$

And

$$x_t r_t' = \frac{x_{t+dt} - x_t}{dt} \qquad (10)$$

So that as dt $\rightarrow 0$ we have $x_{t+dt} - x_t = dx_t$. This implies that

$$x_t r_t' = \frac{dx_t}{dt} \qquad (11)$$

Integrating the above equation from t-1 to t assuming that rt is continuous and differentiable
in (t -1,t) then

$$lr_t \equiv \int_{t-1}^{t} r_t' dt = \int_{t-1}^{t} \frac{dx_t}{x_t} = \log(x_t)\Big|_{t-1}^{t} = \log(x_t) - \log(x_{t-1}) \qquad (12)$$

Normality of the Sea Levels

One of the statistical measures in assessing the distribution of a data is by analyzing the skewness and kurtosis of the data set. Skewness is a measure of symmetry of a data set. A distribution is symmetric if it looks the same to the left or right of the Centre point. For a univariate data x_1; x_2; :::; xn, the skewness according to (Lawrence ,2011) is given by

$$skewness = \frac{1}{n}\frac{\sum_{i=1}^{n}(x_i-\bar{x})^3}{\left[\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^3\right]^{\frac{3}{2}}} \qquad (13)$$

where x is the mean and n is the number of data.

Kurtosis on the other hand is a measure of whether the data are peaked relative to a normal distribution. For a univariate data x_1; x_2; :::; x_n, the kurtosis given by (Lawrence ,2011) is

$$kurtosis = \frac{1}{n}\frac{\sum_{i=1}^{n}(x_{1-}\bar{x})^4}{\left[\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2\right]^2} \qquad (14)$$

where x is the mean and n is the number of data. The histogram is one effective graphical technique for showing both the skewness and kurtosis of a data set. Table 1, gives the descriptive statistics of the sea level.

The empirical distribution of the sea level data can be seen from the histogram in Figure 2 (with Normal line). From the histogram, it can be seen that the distribution of the data is not symmetric and has a long tail to the right. This is justified by an estimated positive skewness of 0.59 (see Table 1). It has a kurtosis of -0.27 < 3, implying that it has a lower peak than the corresponding normal distribution.

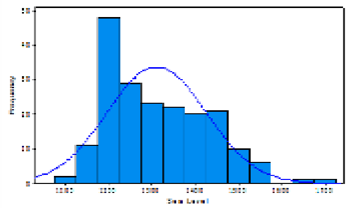

Figure 2: Histogram showing the distribution of the sea levels of the Cape coast with normal curve.

Another statistical tool for checking normality is the Q-Q plot. Its application to the sea level data can be seen in Figure 3, with 95% confidence limits. From the Q-Q plot, it can be observed that most of the percentile points lie outside the 95% confidence limits with the upper and lower tails having extreme values that are falling far away from the Q-Q line. In addition, the Anderson Darling (AD) normality test has a p-value of 0.005 < 0.05 (significance level), indicating a clear rejection from normality. This implies that the distribution of the sea level data cannot be assumed to follow a normal distribution.

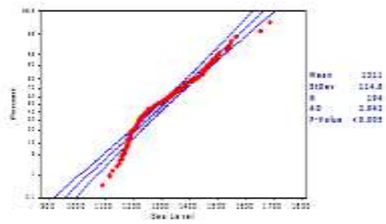

Figure 3: Normal Q-Q plot of the sea level data of the Cape coast with a 95% confidence interval.

The test of significance of the model parameters in Table 2 reveals a highly significant and positive trend in the sea levels of Cape coast. If this trend continues, then approximately the sea levels of Cape coast will rise by 0.96 mm every month and this will have serious implications for flooding of the town. The adjusted R-squared of 0.5096 shows that about 51% of the variations in the sea levels of Cape coast can be explained by the fitted linear trend model and the remaining 49% cannot be accounted for. This may be due to the seasonal component. There is the need to consider modeling further structures in the data.

The significant test of the coefficients of the fitted seasonal plus trend model in Table 3 reveals a highly significant and positive trend in the sea levels of Cape coast. The p-value (<2.2e-16) of the F-statistic which is far less than zero indicates that, the fitted trend plus seasonal model is highly significant. If this trend continues, it will have serious implications for flooding of the town. The adjusted R-square value of 0.9968 indicates that the fitted seasonal plus trend model explains approximately 99.7% of the variations in the sea levels of Cape Coast and this is a significant improvement over the fitted linear trend model.

The fitted quadratic trend model in Table 4 reveals a positive trend in the sea levels of the cape coast (see Figure 4 for the plot). The p-value (< 2.2e-16) of the F-Statistic indicates that the fitted quadratic trend model is significant. The adjusted p-value of 0.5329 shows that about 49% of the variations in the monthly sea levels of cape coast cannot be explained by the quadratic trend model. Comparatively, the quadratic trend model is a slight improvement over the linear trend model even though both models cannot be considered as a good fit for the monthly sea levels of cape coast. The next section will go further to fit a quadratic plus seasonal model to the sea levels of cape coast.

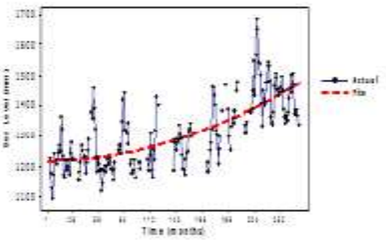

Figure 4: Time Series plot of the monthly sea levels (mm) of cape coast from January to December 2010 with fitted quadratic model given by Yt = 1217:9+0:04t+ 0:0033t2.

The coefficients of the fitted quadratic plus seasonal model reveal a highly significant and positive trend in the sea levels of cape coast (see Table 5). This is backed by a p-value (< 2.2e-16) of the F-statistic which is far less than zero. The adjusted R-square value of 0.997 indicates that the fitted quadratic plus seasonal model explains to a large extend, almost all the features in the cape coast sea levels.

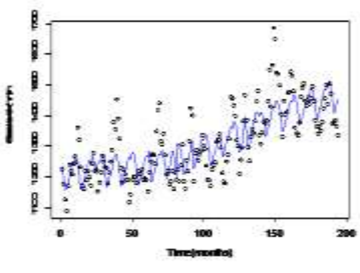

Figure 5: Time Series plot of the monthly sea levels (mm) of cape coast from January to December 2010 with fitted quadratic plus seasonal model showing an increasing trend in the sea levels.

Conclusion

There is the difficulty in fitting an appropriate threshold ranges to a GPD in other to make an accurate fit. Trying to find a threshold requires fitting a GPD several times, each time using a different threshold. Selection of a threshold that is too low will give biased parameter estimates. On the other hand, a threshold that is too high will result in a large variance of the parameter estimates. The instability in the parameter estimates due to different thresholds is of a great concern and must be an important topic for investigations. The GPD model could be further modeled to incorporate seasonal variations in the sea levels. The GPD is appropriate for modeling seasonal changes in threshold exceedance model by specifying a model with different parameters in each season and this was not considered in this study. Further studies in this area could consider such models.

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Table 1: Descriptive statistics of the monthly sea levels and the growth rate Series of the Cape coast sea.

Variable	Mean	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis
Sea level	1310.7	114.8	1091	1687	0.59	-0.27
Monthly growth rate	0.105	4.024	-9.554	9.915	0.1	-0.32

Table 2: Summary table of the fitted linear trend model

Coefficients	Estimate	Std.Error	t value	Pr (>|t|)
Intercept	1177.983	10.9843	107.24	<2e-16***
t	0.9596	0.0576	14.2	<2e-16***

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 80.38 on 192 degrees of freedom
Multiple R-squared: 0.5121, Adjusted R-squared: 0.5096
F-statistic: 201.5 on 1 and 192 DF, p-value: < 2.2e-16

Table 3: Summary table of the fitted trend plus seasonal model

Coefficients	Estimate	Standard Error	t Value	Pr (>|t|)
Trend	0.9657	0.626	15.43	<2e-16***
Jan	1225.345	20.4757	59.84	<2e-16***
Feb	1221.403	21.6232	56.49	<2e-16***
March	1202.213	22.1471	54.28	<2e-16***
April	1166.9	19.8401	58.81	<2e-16***
May	1118.118	19.6144	57.01	<2e-16***
June	1124.352	19.6238	57.3	<2e-16***
July	1148.301	20.0144	57.37	<2e-16***
Aug	1159.713	20.061	57.81	<2e-16***
Sep	1178.107	19.9539	59.04	<2e-16***
Oct	1196.149	21.3623	55.99	<2e-16***
Nov	1209.582	20.562	58.83	<2e-16***
Dec	1204.469	20.3333	59.24	<2e-16***

Table 4: Summary table of the fitted quadratic trend model

Coefficients	Estimate	Standard Error	t Value	Pr (>|t|)
Intercept	1218	16.3	74.714	<2e-16***
t	0.04048	0.2902	0.14	0.8892
t^2	0.0033	0.001015	3.253	0.00135**

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 78.45 on 191 degrees of freedom
Multiple R-squared: 0.5377, Adjusted R-squared: 0.5329
F-statistic: 111.1 on 2 and 191 DF, p-value: < 2.2e-16

Table 5: Summary table of the fitted quadratic plus seasonal model

Coefficients	Estimate	Standard Error	t Value	Pr (>|t|)
t	0.08039	0.2692	0.299	0.7656
t^2	0.003175	0.00092	3.376	0.0009***
January	1264	22.99	54.991	<2e-16***
February	1258	23.66	53.178	<2e-16***
March	1236	23.74	52.064	<2e-16***
April	1203	22.1	54.446	<2e-16***
May	1158	22.38	51.718	<2e-16***
June	1164	22.36	52.04	<2e-16***
July	1187	22.59	52.555	<2e-16***
August	1198	22.59	53.044	<2e-16***
September	1219	22.94	53.159	<2e-16***
October	1238	24.13	51.291	<2e-16***
November	1249	23.1	54.051	<2e-16***
December	1243	22.78	54.542	<2e-16***

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 72.27 on 180 degrees of freedom
Multiple R-squared: 0.9972, Adjusted R-squared: 0.997
F-statistic: 4580 on 14 and 180 DF, p-value: < 2.2e-16